When a second language hits a native language.
What ERPs (do and do not) tell us about language retrieval difficulty
in bilingual language production.

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Author note: Upon acceptance, all raw data (including the raw EEG recordings) and the code needed to reproduce all results will be made publicly available.

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ABSTRACT

The accumulating evidence suggests that prior usage of a second language (L2) leads to processing costs on the subsequent production of a native language (L1). However, it is unclear mechanism underlies this effect. It has been proposed that the L1 cost reflects inhibition of L1 representation acting *during* L1 production; however, previous studies exploring this issue were inconclusive. It is also unsettled whether the mechanism operates on the whole-language level or is restricted to translation equivalents in the two languages. We report a study that allowed us to address both issues behaviorally with the use of ERPs while focusing on the consequences of using L2 on the production of L1. In our experiment, native speakers of Polish (L1) and learners of English (L2) named a set of pictures in L1 following a set of pictures in either L1 or L2. Half of the pictures were repeated from the preceding block and half were new; this enabled dissociation of the effects on the level of the whole language from those specific to individual lexical items. Our results are consistent with the notion that language after-effects operate at a whole-language level. Behaviorally, we observed a clear processing cost on the whole-language level and a small facilitation on the item-specific level. The whole-language effect was accompanied by an enhanced, fronto-centrally distributed negativity in the 250–350ms time-window which we identified as the N300 (in contrast to previous research, which probably misidentified the effect as the N2), a component that presumably reflects retrieval difficulty of relevant language representations during picture naming. As such, unlike previous studies that reported N2 for naming pictures in L1 after L2 use, we propose that the reported ERPs (N300) indicate that prior usage of L2 hampers lexical access to names in L1. Based on the literature, the after-effects could be caused by L1 inhibition and/or L2 interference, but the ERPs so far have not been informative about the causal mechanism.

KEYWORDS

bilingual language production, language after-effects, inhibition, N2, N300

INTRODUCTION

Anyone who has experienced speaking another language for a long time is familiar with the feeling of difficulty related to returning to one's own native language. In extreme instances, the feeling is subjectively experienced as if the native language has been temporarily 'lost'. In laboratory settings, this 'language after-effect' has been documented either in the form of retrieval-induced forgetting (RIF; Levy, McVeigh, Marful, & Anderson, 2007; but see Runnqvist & Costa, 2012 for counter evidence), reduced verbal fluency (van Assche et al., 2013; Linck et al., 2009), the tip of the tongue phenomenon (Kreiner & Degani, 2015), or a mere slow-down of L1 after L2 (e.g. Branzi et al., 2014). The goal of the current study was to examine the neurocognitive processes leading to slower naming in L1 after naming in L2. To this aim, behavioral responses and event-related potentials (ERPs) were recorded while participants were naming simple objects in their L1. L1 naming was preceded by either naming in L2 or by naming in L1. We focused on the relatively long-lasting after-effects observed across language-consistent naming blocks.

Mechanisms of language after-effects

Previous research investigating cognitive mechanisms of bilingual language production has implicated language inhibition as a possible explanatory mechanism underlying the observed difficulties of speaking L1 after L2. The idea behind this is based on the Inhibitory Control model (IC; Green, 1998) and assumes that the stronger language (L1) needs to be inhibited in order for the weaker language (L2) to be spoken. Thus, under the IC model the L1 retrieval difficulty after L2 use is a result of L1 inhibition. Most behavioral evidence that has been interpreted in favor of the inhibitory account comes from studies that

employed a language-switching paradigm¹ in which participants need to switch from naming in one language to another on a trial-to-trial basis (for a review see Bobb & Wodniecka, 2013; Declerck & Philipp, 2015). In this paradigm, the larger cost of switching into the dominant language than into the weaker language (the so-called language switch cost asymmetry) has been typically considered a marker of inhibition of the dominant language. A recent reanalysis of the data from language switching paradigm conducted by Kleinman and Gollan (2018) has been interpreted by the authors as evidence for the presence of inhibition in bilingual language production. Also, such an interpretation has been advocated by several authors who used the language-switching paradigm and explored neural activation related to L1 retrieval difficulty (e.g. Guo et al., 2011; Fu et al., 2017; Hut et al., 2017).

However, not all previous studies have provided clear support for language inhibition; other accounts that assume no inhibition in bilingual language production have been proposed as well (for a review see Kroll & Gollan, 2014). For example, the persisting activation account (for a review see Koch, Gade, Schuch, & Philipp, 2010) proposes that slower naming in an L1 trial following an L2 trial can be explained by lingering activation of L2 during the L1 trial. The logic behind this proposal is the following: because bilinguals are typically more proficient in their native language, they have stronger residual activation of L1 than of L2. Therefore, when they name pictures in L2 they have to activate the language more strongly to surpass the L1 activation. When they subsequently switch to naming in L1, this enhanced activation of L2 may lead to carry-over effects on the subsequent L1 naming trials, thus increasing the time necessary to name items in L1.

Beside the still unclear nature of the mechanisms underlying the language after-effects, an under-studied issue concerns the scope of the reported word-retrieval difficulty

¹ More recently, also other paradigms such as n-2 repetition paradigm have also been employed (Declerck, Thoma, Koch, & Philipp, 2015).

observed after production in another language. One possibility is that the difficulty is item-specific, i.e. naming a picture of a dog in one language hampers production of the word corresponding to 'dog' in another language. Another option is that the difficulty concerns the whole language, i.e. naming in one language temporarily hampers production of any words in other languages known (De Groot & Christoffels, 2006). In the already mentioned recent re-analysis of data from language switching studies, Kleinman and Gollan (2018) argue for the presence of inhibition at multiple processing levels, including language-wide global inhibition as well as item-specific lateral inhibition for translation equivalents.

However, the classic language-switching paradigm described above may not be the most straightforward method of testing after-effects in language production because successful performance in this task necessarily requires active maintenance of both languages (Monsel, 2003); it also typically involves multiple repetition of items, which - if not strictly controlled for - may introduce effects that confound the language after-effects. This, in turn, complicates unbiased testing of the mechanisms underlying regulation of default activation between the two languages and makes it difficult to disentangle the whole-language after-effects from item-level effects (for a detailed review of some other problems with the language switching paradigm, see Bobb & Wodniecka, 2013). Because of the limitation of the language switching paradigm, some researchers interested in language after-effects at the whole-language and/or item-specific level have recently turned to the blocked language production paradigm, in which what alters are the entire blocks of naming in either L1 or L2, each typically lasting at least 1 minute.

Previous behavioral and electrophysiological evidence of language after-effects in the blocked language paradigms

To the best of our knowledge, only a few studies have used the blocked language production paradigms to directly examine the cognitive mechanism of whole-language and/or item-specific language after-effects. Below, we will focus on three published reports that collected behavioral and/or electrophysiological data, and therefore are most relevant for the current study.

Van Assche et al., (2013) used phonological verbal fluency to assess the difficulty of language production in L1 and L2. The authors tested two groups of language-unbalanced bilinguals who differed both in languages they spoke (Dutch–English and Chinese–English) and in terms of whether they were immersed in their L1 (Dutch–English bilinguals) or their L2 (Chinese–English). The participants completed a phonological verbal fluency task first in L2 and then in L1. The authors manipulated whether the participants produced words starting with the same or different letter/phoneme in L2 and L1 blocks. They assumed that producing names starting with the same letter in L2 and L1 leads to an item-specific interference effect (e.g. producing names starting with ‘k’ in one language hampers production of names starting with ‘k’ in the other language), whereas producing names starting with a different letter in each language leads to interference at the whole-language level. In the authors’ interpretation, both participant groups revealed item-specific L1-after-L2 effects. That is, bilinguals produced significantly fewer words in L1 when the preceding L2 block required production of names starting with the same phoneme, relative to when the preceding L2 block required production of words starting with a different phoneme. Moreover, participants who were immersed in their L2 had difficulty in word retrieval at the whole-language level (i.e. produced fewer names starting with a different phoneme in each language). As such, the study by Van Assche et al. suggests that in controlled word production, item-specific and whole-

language effects may be driven by distinct mechanisms that are differentially recruited depending on the given language context².

The two other studies that looked at mechanisms of language after-effects obtained both behavioral and ERP data; this gave the opportunity not only to observe the end-point of neural processing (i.e. reaction time data or accuracy) but also to track online the processes leading to the behaviorally observable outcomes. In the study by Misra, Guo, Bobb, and Kroll (2012), unbalanced Chinese–English bilinguals named the same pictures in their two languages in four blocks (each picture was named four times). Half of the participants named pictures in order L1–L1–L2–L2, while the other half in order L2–L2–L1–L1. The comparison that is relevant to the present study tested the effects of prior L2 naming on the subsequent naming of pictures in L1 (i.e. the comparison between the first block from the L1–L1–L2–L2 order vs. the third block from the L2–L2–L1–L1 order). The authors observed no difference in the latency of L1 naming between the two blocks (i.e. no language after-effect). Within the ERPs, they did, however, observe a negativity in the 250–375 ms time window that had a broad scalp distribution for L1 naming following L2 naming (as compared to L1 naming not preceded by L2 naming). The authors interpreted this negativity as an N2 component and concluded that it reflects inhibition of the more dominant L1 after a block of L2 naming³. Even though there were no differences in naming latencies between the critical blocks, the authors argued that repetition of a picture and a concept should lead to facilitation (due to repetition of the processes involved), so the absence of a clear facilitation effect likely resulted from the facilitation and inhibition processes canceling each other out. The study by

² Because the language pairing and language context were confounded in the Van Asche et al. study, it is unclear which of the factors is critical for determining the presence of the whole-language effect.

³ Such an interpretation stems from a research tradition which dates back to the seminal study by Jackson et al. (2001) and is still present in the field of research on bilingualism. Within this tradition, it is assumed that language inhibition should be reflected by the N2 component, the same component that occurs in the go-nogo task in the 200–320 ms time window on fronto-central electrodes and it is thought to reflect response conflict or inhibition of prepotent response (for a review see Folstein & van Patten, 2008).

Misra et al. could not disentangle the item-specific from the whole-language effects because the design did not include L1 naming of new pictures following L2. Moreover, the study had two methodological limitations. Firstly, the critical manipulation was between-subject, which most likely produced large variability in ERPs across subjects and possibly led to a substantial decrease in signal-to-noise ratio. Secondly and more importantly, the relevant comparison (i.e. L1 naming preceded by L2 naming vs. L1 naming not preceded by L2 naming) included conditions which differed not only in the critical manipulation but also in the number of repetitions of a given picture to be named, as well as in the ordinal number of a trial. As such, the two compared conditions differed also in the amount of practice or ease with which pictures were recognized. Therefore, the ERPs reflect the possible contribution of several factors, making it impossible to distill the language after-effects and separate the item-level from the whole-language effects.

The second study that investigated ERP correlates of language after-effects in blocked picture naming (Branzi et al., 2014) explicitly addressed the distinction between item-specific and whole-language after-effects while circumventing some of the limitations of the study by Misra et al. Highly proficient Spanish–Catalan bilinguals were asked to name different sets of pictures across three blocks. The comparison that is most relevant for the current investigations concerns the difference between the first and the third picture naming block in an L1–L2–L1 series of blocks. The two blocks differed with respect to whether L1 naming was preceded by L2 naming (*L1-start* vs. *L1-return* in the terminology used by Branzi et al.). Half of the pictures in the third block were repeated from the preceding block of naming in L2, while the other half of the pictures were new (*L1-return-repeated* and *L1-return-new* conditions in Branzi et al.). This enabled Branzi et al. to distill item-specific and whole-language after-effects. With respect to the after-effects on the whole-language level (*L1-start* vs. *L1-return-new*), Branzi et al. found longer naming latencies for new pictures named in L1

after a block of naming in L2, compared to new pictures named in L1 in the first block. This implied that L2 naming hinders subsequent L1 naming, even of completely new pictures. As such, the results provided evidence for after-effects on the whole-language level. In the ERPs, the authors found a broadly distributed positivity for the after-L2 condition, starting at 170 ms (as indicated by visual inspection) and lasting at least until the end of the recorded epoch (500 ms; see Figure 7 in Branzi et al.). The earlier portion of this effect was not significant, while the later portion, analyzed in the 300–500 ms time-window, they interpreted as an “attenuation of the N2 component for the L1 when it must be recovered after naming in the L2” (p. 109). With respect to item-specific after-effects (*L1-start* vs. *L1-return-repeated*), the authors reported only behavioral results. As in the study by Misra and colleagues (2012), there were no differences in naming latencies between the before- and after-L2 conditions. However, unlike Misra et al., Branzi and colleagues speculated that the absence of facilitation was not due to facilitation and inhibition cancelling each other out, but to the fact that the stronger L1 does not benefit from repetition of a picture for which a label in L2 was produced previously. One methodological limitation of the design used in the study by Branzi et al. is that, just as in the study by Misra et al., in the comparison between the first and the third block, effects of practice were not controlled (i.e. while the third block was preceded by two blocks of naming, the first block was not).

In sum, the results of the experiments looking at the language after-effects seem to offer a very discrepant and inconsistent picture. In behavioral results, Van Assche (2013) argued that they found clear item-level effects, while both Branzi et al and Misra et al. found no clear evidence for the item-level effects. With respect to the whole-language after-effects, Van Assche et al. found them only in bilinguals who were immersed in their L2, while Branzi et al. found them for bilinguals living in their home country. With respect to the ERPs, the available picture is equally unclear. Branzi et al. found a large, long-lasting, widely

distributed positivity for whole-language effects, visually starting from 175 ms and lasting to the end of the recorded epoch, while Misra et al., for item-level effects (also, by necessity subsuming whole-language effects) found a negativity in the 250–375ms time-window. Therefore, the available evidence offers no single point of convergence. The described differences might stem from the apparent heterogeneity of the tasks used to measure the after-effects (verbal fluency vs. various modifications of blocked picture naming) as well as from the methodological constraints. Moreover, some of the ERP results should be interpreted with caution. For example, visual inspection of the graphs presented by Branzi et al. suggests that the ERPs could be affected by an artifactual, large negative drift in the *L1-start* condition (the ERPs for the *L1-start* condition diverge from those for all other conditions from the very onset of the epoch, see Figs. 3, 4, 7), leading to the positivity observed in the *L1-return-new* condition, relative to *L1-start*.

The present study

The aim of the present study was to explore the consequences of naming pictures in L2 on the subsequent naming of pictures in L1 (the L1-after-L2-effect) and to test whether the after-effects occur at the whole-language and/or the item-specific level. We investigated the behavioral effects and their ERP correlates while employing a blocked language production paradigm. This paradigm follows the logic of the studies by Misra et al. (2012) and Branzi et al. (2014); however, in contrast to these studies it focuses only on testing the consequences for the native language. Similarly to the study by Branzi et al. (2016), we manipulated both within- and between-language repetition (L1 after L1 vs. L1 after L2), which allowed us to assess how the repetition of items contributes to observed ERP effects. Moreover, we attempted to circumvent some of the pitfalls of the previous investigations by 1) using a within-subject design, 2) increasing statistical power by testing a much larger participant

sample, and 3) controlling the effects of practice by ensuring that the compared naming conditions were preceded by the same amount of (filler) picture naming.

Figure 1. Overview of the task design.

Figure 1 presents the most important features of our paradigm. Naming was performed in two stages, separated with 30 min of other tasks in L1. Within each testing stage, there were two naming blocks of 60 pictures each: L1–L1 in the first stage and L2–L1 in the second stage. The analyses were performed only on the data from the second block of each stage (i.e. both on a block in L1), whereas pictures presented in the first blocks of each stage served as fillers that set up the language context. The comparison between the stages led to the first factor (Preceding Language) with two levels: after L1 (second block of the first stage), and after L2 (second block of the second stage). In each stage, half of the pictures were shared between the blocks (i.e. presented both in the first and in the second block), while the other half were unique and not presented in any other block. This constituted the second factor in our study (Repetition) with two levels: new (pictures unique to the block they occur in) and repeated. Preceding Language and Repetition were crossed in a 2 by 2 design, leading to four experimental conditions: *new-after-L1*, *repeated-after-L1*, *new-after-L2*, *repeated-after-L2*.

This design allowed us to explore two types of language after-effects: (1) concerning the whole language (i.e. the whole-language after-effect) and (2) specific items (i.e. item-specific after-effects). The first was assessed by comparing *new-after-L1* and *new-after-L2*

conditions whereas the latter was assessed by comparing *repeated-after-L1* and *new-after-L1* conditions and between *repeated-after-L2* and *new-after-L2* conditions.

On the behavioral level, the predictions for the whole-language after-effects are straightforward: we expected a significant slowdown of L1 naming after a block of L2 naming, relative to L1 naming after a block of L1 naming. With respect to the item-specific L2 after-effects (comparison between *repeated-after-L2* and *new-after-L2* conditions), we do not expect the behavioral data to be conclusive: On the one hand, if naming a given picture (e.g. a dog) in one language inhibits its translation equivalent in the other language, one would expect prolonged naming latencies in the *repeated-after-L2* condition. On the other hand, however, repeated naming of the same picture should lead to some facilitation. This facilitation, which is caused by the repeated recognition of the same picture, should counteract the hypothesized inhibitory effect. Because the relative strength of the facilitation and of the inhibition is unknown, any result involving a facilitation could be explained by a joint contribution of the two processes, each counteracting the other one. Although others have argued that mere absence of facilitation in the *repeated-after-L2* condition can be considered as clear evidence for inhibition (e.g. Misra et al., 2010; Guo et al, 2011), we present here a more conservative view: Only clearly longer naming latencies in the *repeated-after-L2* (compared to *new-after-L2*) condition could be unambiguously interpreted as an argument in favor of item-level inhibitory after-effects⁴. The above ambiguity reveals the limitation of reaction times which measure only the ultimate outcome of a cascade of latent processes leading to the verbal response. In contrast, the ERPs open the possibility to observe and measure each of those processes separately. If we were to take the previously discussed ERP

⁴ A smaller facilitation in the *L1 after L2* condition for repeated pictures compared to the *L1 after L1* condition can be explained by inhibition, but it can also be explained by reduced repetition priming. That is, repeated naming of pictures in the same language (L1 after L1) likely involves priming of both picture recognition and lexical retrieval. Repeated naming of pictures in a different language (L1 after L2), on the other hand, may involve only priming of picture recognition but not of lexical access because when the picture was previously named, a different name was used.

results and their interpretations at face value and—based on the fact that the participants of the current study were highly proficient but language-unbalanced bilinguals (similarly to the study by Misra et al.)—we should replicate the findings by Misra et al. That is, for the whole-language level, if the slowdown of L1 is caused by inhibition of L1 occurring *during* L1 production, then—under the broad assumption that N2 reflects inhibition—we should observe the N2 component in the *after-L2* condition, but not in the *after-L1* condition. Similarly, if the L2 after-effects involve inhibition at the item-specific level, we should observe a more negative N2 component in the *repeated-after-L2* condition, relative to the *new-after-L2* condition.

METHOD

Participants

Seventy-nine students from three secondary schools in Krakow volunteered to participate in the study (mean age = 16.4 years, SD = 0.5; 56 female; 73 right-handed). The experiment met the requirements and gained the approval of the Ethics Committee of Jagiellonian University Institute of Psychology concerning experimental studies with human subjects. Since our participants were underage, written informed consent for participation was given both by the participants and by their parents prior to the experiment. After completing the experimental session, all participants received small gifts and were included in a prize lottery. Background information on participants' self-assessed language proficiency, learning history and extent of language use were collected with a language background questionnaire based on Li, Sepanski, and Zhao's questionnaire (2006). All participants were language-unbalanced Polish–English bilinguals whose only language acquired in early childhood was Polish. On average, they first started learning English in primary school at the age of 5.7 (SD

= 2.2). They started using English more intensively when they started attending junior high school around the age of 13. All participants declared they had started learning another foreign language (L3; predominantly German or French), but their L3 proficiency was low and they did not speak L3 outside the classroom context. All participants reported using mostly L1 during an average day and speaking L2 only occasionally, mostly during English lessons at school. Similarly, participants considered their L1 proficiency significantly higher than L2 (for detailed self-assessment data see Table 1). To obtain an objective L2 proficiency measure, we also asked participants to fill in the Lexical Test for Advanced Learners of English, LexTALE (Lemhofer, Broersma, 2011). On average, participants obtained a score of 67% (SD = 11%), indicating that they were moderately proficient in their L2. We also assessed their semantic verbal fluency scores both for L1 and L2 (participants produced as many words as possible in 60 s in each language separately; the categories were animals, fruits & vegetables, body parts, rotated across the participants and languages). Participants produced significantly more words belonging to the target semantic category in L1 than in L2 (see Table 1).

	L1	L2
Self-rated proficiency (1–7) ¹	6.92 (0.18)	5.25 (0.73)
Percentage of daily use	74.59 (16.77)	17.37 (12.42)
LexTALE (mean accuracy in %)	-	66.97 (10.64)
Semantic verbal fluency task (number of words produced in 60 s)	21.6 (5.1)	15.4 (5.3)

Table 1. Participants' mean proficiency and daily use of L1 and L2 based on self-assessment questionnaire and LexTALE (standard deviations given in parentheses).

¹ ratings in a questionnaire in which participants self-assess their proficiency on the scale 1-7, where 1 = no knowledge of given language, 7 = native-like proficiency in given language.

Task and procedure

Materials. Stimuli in the picture-naming task included 180 pictures selected from the online database of the International Picture Naming Project (Szekely, Jacobsen, et al., 2004). All pictures were black-and-white line drawings sampled from a range of semantic categories; no Polish–English cognates were included. The pictures were divided into six bins of 30 pictures, each matched in visual complexity, length of most common names in Polish and English, age of acquisition in English, and the frequency of the dominant Polish and English name (Polish: SUBTLEX-PL; Mander et al., 2012; English: SUBTLEX-US; Brysbaert & New, 2009). The six sets were rotated across the experimental conditions such that, across participants, each picture occurred in each condition.

Procedure. Each trial began with the presentation of a blank screen with random duration (700–1300 ms) followed by the presentation of a fixation point in the center of the screen for 1000 ms. Subsequently, the fixation point was replaced by the target picture until the timeout (3000 ms) or a response. The stimuli were presented using DMDX software (Forster & Forster, 2003) on a 17-in. screen positioned approximately 80 cm from the participant. Participants were instructed to name pictures aloud as quickly and accurately as possible. Reaction times for vocal responses were recorded; naming latencies were automatically measured using a DMDX voice key and subsequently manually screened for any artifactual sounds. The task was administered in two testing stages, separated by administration of other tasks in L1 for approx. 30 minutes (see Figure 1 above). Within each testing stage, there were two blocks of picture naming with 60 pictures each. The critical block in terms of further analyses was the second block of each testing stage, in which participants named pictures in their L1 (Polish). These blocks of L1 naming were preceded by a block of filler naming, either in L1 (first block of the first testing stage) or in L2 (the first block of the second testing

stage; see Figure 1). This constituted the two-level factor: Preceding Language (after L1 vs. after L2). Half of the pictures used in the second blocks of each testing stage were new, and half were repeated from the preceding block. This constituted another two-level factor: Repetition (new vs. repeated; see Figure 1). The information concerning the target language for each block was presented at the onset of the block. Participants completed 8 practice trials before the onset of the first block in each testing stage. Participants were asked to take a short break between the first and the second block of each testing stage. Each of the blocks lasted approximately 10 minutes. Overall, participants named 180 unique pictures, 60 of them twice (the repeated conditions).

Electrophysiological Recording

The electroencephalogram (EEG) was recorded at 256 Hz from 32 Ag/AgCl scalp electrodes positioned at the standard 10–20 locations, mounted in an elastic cap, using the Biosemi Active Two recording system. Electrodes were initially referenced online to the Common Mode Sense electrode located at the C1 electrode and re-referenced offline to the mean of the left and right mastoids. The horizontal and vertical electro-oculogram (EOG) was recorded bipolarly using electrodes placed below and above a participant's right eye and at the outer canthus of each eye, respectively. The EEG signal was offline filtered with a band-pass filter (0.05 Hz – 25 Hz frequency range; low cutoff slope: 24 dB/oct; high cutoff slope: 12 dB/oct).

Reaction time data analysis

Prior to running the analyses, for each participant we removed all trials with errors, timeout, extremely short naming latencies ($> 300\text{ms}$), as well as trials with recordings too quiet to recognize the response. For pictures in the repeated condition, we also removed from the

analysis the trials (pictures) that were erroneously named in the preceding block. In other words, repeated pictures had to be named correctly in both blocks to be included in the analyses. Response latencies were transformed using a reciprocal transformation ($-1000/RT$) due to right-skewed distribution of the data.

EEG data analysis

ERP data were analyzed using a BrainVision Analyzer. Six participants were removed from the EEG analyzes due to a very noisy signal and strong skin potentials, thus leaving 73 participants for the final analyses. Epochs of 150 ms before and 900 ms after stimulus onset were extracted from the continuous EEG and baseline-corrected according to a 150 ms window before stimulus onset. Independent Components Analysis was used to remove ocular and other stationary artefacts (Delorme, Sejnowski, & Makeig, 2007; Jung et al., 2000). Afterwards, all trials were manually inspected to remove any remaining artefacts. On average, 4.4% of trials were removed. Stimulus-locked ERP averages (which only included correct trials) were computed individually for each participant and separately for the four conditions resulting from crossing the factors of Preceding Language and Repetition (see Figure 1). Because language production is associated with strong facial muscle and glosso-kinetic artifacts, we restricted the ERP analysis to uncontaminated time-windows. Speech production related artifacts occur up to 300 ms before the speech onset (Fargier, Bürki, Pinet, Alario, & Laganaro, 2018; Ouyang et al., 2016). Because the analyzed component occurred in the 250-350ms time-window, we restricted the analysis to trials with reaction times longer than 650ms (90% of trials).

Statistical analyses

All analyses (behavioral and ERP) were performed using linear mixed effects models, as implemented in the lme4 package (version 1.1-13; Bates, Mächler, Bolker, & Walker, 2015) in R using participants and pictures as crossed random effects. As fixed effects we included the Preceding Language and Repetition factors and their interaction. We also included the trial number as a predictor to control for effects of familiarization or fatigue during the experiment. All categorical predictors were deviation coded and the continuous predictor Trial was centered prior to running the analyses. The models also included by-item and by-subject random intercept and random slopes for all variables, but no interactions between them.

RESULTS

Behavioral results

Overall, participants had a high accuracy when naming in L1 and a lower accuracy when naming in L2 (see Table 2, upper section). Because repeated pictures had to be named correctly in both blocks to enter the analysis, 10% fewer pictures were taken into account in the behavioral and ERP analyses when L1 naming was preceded by a block of L2 naming, compared to when L1 naming was preceded by another block of L1 naming (see Table 2, lower section).

Testing Stage	Block 1		Block 2	
	Lang.	Mean (SD)	Lang.	Mean (SD)
Raw accuracy				
1 (L1-L1)	L1	.94 (.06)	L1	.95 (.08)
2 (L2-L1)	L2	.75 (.12)	L1	.94 (.06)
Accuracy conditioned on the preceding block				
1 (L1-L1)			L1	.93 (.09)
2 (L2-L1)			L1	.83 (.08)

Table 2. By-participant mean accuracy for naming in all testing stages and blocks. Upper section: Raw accuracy scores. Lower section: Accuracy in the second blocks, with accuracy recoded to 0 for those repeated pictures that in the preceding block were named incorrectly.

The analysis of reaction latencies showed significant fixed effects of Preceding Language, Repetition, and a significant interaction of Preceding Language and Repetition (see Table 3 and Figure 2). Participants showed the *L1 slowing effect*: they were slower to name pictures in L1 after a block in L2, compared to naming pictures in L1 after a block in L1. Repeated naming of the same pictures resulted in facilitation, compared to naming new pictures. This effect was much larger when the pictures were previously named in the same language (L1) than when the pictures were previously named in the other language (L2); however, even for L1 naming after L2, the facilitation effect was still significant ($t = -2.29$). There was also an effect of (log) Trial number, indicating that as the experiment progressed, participants were slower to name the pictures.

Effect	Estimate	SE	t	by-Item SD	by-Subject SD
Intercept	-1.16	0.02	-68.11	0.11	0.13
Repeated	-0.09	0.01	-10.37	0.06	0.04
Preceding Language	0.17	0.01	12.47	0.04	0.11
Repeated: Preceding Language	0.1	0.02	5.6	0.06	0.11
log(TrialN)	0.13	0.01	10.12	0.06	0.06

Table 3. Fixed and random effects for the LME model of reaction latencies.

Figure 2. Visualization of the LMM estimates for mean reaction latencies for new and repeated pictures preceded by L1 or L2 block. Whiskers represent 95% confidence intervals.

EEG results

Figure 3 shows the ERPs for the four conditions resulting from the two factors: Preceding Language and Repetition. Visual inspection of EEG revealed two distinct modulations. The first modulation has a central distribution and occurs in the 250–350 ms time window. Initially, based on the preceding literature (see Introduction), we interpreted it to be the N2 ERP component. However, after seeing how the ERPs corresponding to the four experimental conditions are layered within this modulation, we reinterpreted this component as the N300 component. In the Discussion we provide rationale for this interpretation. The second modulation is presumably the LPC component; it peaks in the 450–600 ms time window at centro-parietal loci. However, this component could not be analyzed due to its contamination

with articulatory artifacts⁵. To quantify the differences in the ERPs across the conditions for the N300 we analyzed the average ERPs in the 250–350 ms time window, averaged from electrodes FC1, FC2, C3, Cz, C4, CP1, and CP2.

Figure 3. Average ERPs for the four conditions in the task. Panel A shows grand-averaged ERP waveforms for the new (solid line) and repeated (dashed line) conditions, crossed by after L1 (black) and after L2 (red) conditions, measured at the midline frontal (Fz), central (Cz) and posterior (Pz) electrode sites. Panel B shows difference scalp maps in the N300 time window for the comparison after L2 minus after L1 and for new minus repeated.

⁵ An analysis of a component in the 400–600ms time-window would require rejecting all trials with reaction times shorter than 900ms. Besides, we have no a-priori predictions concerning the LPC component.

N300. The results of the analysis of the N300 are shown in Table 4 and Figure 4. Linear mixed effects models revealed significant additive effects of Preceding Language and Repetition: the amplitude of the N300 was reduced when participants named pictures they had already named; it was also reduced when participants named pictures in the same language as in the preceding block (L1 after L1 vs. L1 after L2). The interaction of Preceding Language and Repetition was not significant; the effect of Trial number was also not significant.

Effect	Estimate	SE	T	by-Item SD	by- Subject SD
Intercept	0.1	0.78	0.13	2.26	4.84
Repeated	2.33	0.31	7.59	1.33	0
Preceding Language	-1.34	0.4	-3.33	1.31	2.18
Repeated: Preceding Language	0.48	0.63	0.77	1.89	1.55
log(TrialN)	-1.44	0.82	-1.75	0	2.9

Table 4. Fixed and random effects for the LME model of mean amplitudes of the N300.

Figure 4. Visualisation of the LMM estimates of the mean amplitude of the N300 ERP component. Whiskers represent 95% confidence intervals. Note that the Y-axis is inverted to match the ERP plots.

DISCUSSION

In the present study, we explored the effects of speaking L2 on subsequent speaking in L1 (the L1-after-L2 effect) on both a behavioral and electrophysiological level. We attempted to dissociate two possible L1-after-L2 effects which differ in scope: one that pertains to the level of the whole language and the other that relates to the level of specific lexical items. To this aim, we independently manipulated the language in which the preceding block of pictures was named (Preceding Language); we also manipulated whether the pictures in the current block were repeated from the preceding block or not (Repetition).

On the behavioral level, we observed a whole-language (L1) slowing effect (i.e. naming new pictures in L1 was slower when it followed L2 naming, compared to when it followed a

block of L1 naming). This result indicates that prior naming in L2 leads to subsequent retrieval difficulty of the lemmas in L1, which is in accordance with the previous findings of Branzi et al. (2014). However, the behavioral data themselves do not provide direct information about the mechanism that drives the effect. The whole-language effect can be explained in terms of massive L1 inhibition (which would support the claims of the IC model, Green, 1998) or in terms of L2 interference caused by lingering activation of L2 that carries over to the subsequent block of naming in L1 and thus interferes with access to L1 representations (e.g. Koch, Gade, Schuch, & Philipp, 2010). We will subsequently refer to this alternative account as the L2 interference account.

We also observed facilitation stemming from repeated naming of the same picture; this benefit was particularly apparent in the *repeated-after-L1* condition (repeated naming of the same picture in the same language). The effect was expected and most likely driven by facilitated identification of the same picture and facilitated retrieval of the same label upon second naming of the same picture in the same language (L1; see also: e.g. Barry, Hirsh, Johnston, & Williams, 2001; Mitchell & Brown, 1988). We also observed some, albeit much smaller, facilitation in the *repeated-after-L2* condition in which the picture itself was repeated but had previously been named using a different label in a different language. Although in previous studies similar effects have been taken as evidence of inhibition of translation equivalents (e.g. Misra et al, 2010), as we indicated in the Introduction (see Footnote 4) our stance is that such an effect could be interpreted both as reduced repeated naming in the *after-L2* condition compared to the *after-L1* condition, or as a mix of facilitation and an inhibitory after-effect at the item-level level. Therefore, we conclude that the behavioral results do not provide clear evidence for item-level locus of the after-effects, although the results are consistent with the idea of L1-after-L2-effects at the whole-language level.

In the electrophysiological recordings we found two modulations. The first modulation was a centrally-distributed modulation in the 250–350 ms time window, peaking at 300 ms. The functional interpretation of this component is not straightforward because, as argued in the Introduction, ERP correlates of bilingual language production are still not very well understood and studies of language-after-effects employing ERPs are scarce. In the previous study that looked at language after-effects in bilingual picture naming (Misra et al., 2012), a component similar to the one reported here was interpreted as the N2 component. We propose an alternative interpretation of the obtained effect, namely that it reflects the N300 component rather than the go/no-go N2. In the section below, we provide a more detailed explanation of our account.

Why is the observed modulation unlikely to correspond to the no-go N2 component?

As indicated in the Introduction, previous research on bilingual language production which aimed to test the inhibitory control model sought the N2 component for L1 naming when it followed a block of L2 naming. The N2 component (i.e. a fronto-central N2 occurring in the 200–320 ms time window) typically occurs in go/no-go tasks which require inhibition of a response to a prepotent stimulus. Based on the claims made in the literature on response inhibition (Folstein & Van Petten, 2008; Pires et al., 2014), the presence of the N2 component in the L1-after-L2 condition could by extension be taken as evidence for inhibition of a prepotent response in L1 (see e.g. Misra et al., 2012). However, we believe that the interpretation of the modulation observed in the blocked language paradigm in terms of the N2 component is, in fact, not warranted. Below, we discuss arguments that led us to the reinterpretation of the effects.

First, the pattern of ERP results in the current experiment is incompatible with the interpretation that the negativity reflects the N2 component. To demonstrate our point, we will

focus on the fact that *new-after-L1* condition elicited a more negative amplitude than the *repeated-after-L1* condition. If the observed modulation in this time-window reflected the no-go N2 component, it would follow that naming pictures in L1 involves inhibition. Such interpretation, however, would make no sense, as this condition involved L1 naming under a default L1 activation (the participants entered this condition after being previously immersed in L1, so their L1 was activated at a default level). As such, the *new-after-L1* condition did not set any special requirements for language inhibition, so the interpretation of the observed ERP modulation in terms of inhibition of prepotent responses does not adhere to the pattern of results obtained in this study.

Second, the association of the L2 after-effects with the no-go N2 component requires making the following, rather problematic assumption. According to the inhibition theory of the no-go N2, the component reflects inhibition of an already prepared response (Folstein & Van Petten, 2008). As such, if we were to find evidence of L1 inhibition *during* L1 naming following a block of L2 naming, we would need to assume that inhibition takes place each time a speaker attempts to name a picture in L1 in this *after-L2* block. This seems highly unlikely and contradicts the assumption of the IC model, according to which inhibition primarily concerns the more dominant L1 and it occurs during L2 production rather than during L1 production. This leads us to conclude that during L1 naming that follows a block of L2 naming, we could only observe the consequences of the inhibition (i.e. the L2 after-effects) but not the inhibition per se. Therefore, even the mere expectation of finding a reflection of inhibitory processes (i.e. the no-go N2 component) in the block of L1 naming seems unwarranted.

The N300 rather than the no-go N2 component

Given all the arguments discussed above, instead of interpreting the observed modulation as the no-go N2 component, we considered another interpretation stemming from outside the bilingual language processing domain. In tasks that use pictures as critical stimuli, it has been typically observed that the presentation of a picture leads to a family of fronto-central (when mastoid reference is used) negativities occurring between 250 and 350 ms. In the literature, it is also referred to as the N3, N350 or N3 complex to account for its somewhat varied onset latency and often absence of a clear peak. For the sake of simplicity, we will refer to the component as N300. Below, we briefly review the most important findings concerning the N300.

The component is sensitive to a range of factors that affect recognition of pictures. For example, the N300 gets reduced when participants successfully identify incomplete pictures (Schendan & Kutas 2002). Pictures that are ambiguous and thus have a low name agreement elicit larger N300 amplitude relative to pictures with high name agreement (Shao et al., 2004). Similarly, pictures that belong to a learned category of abstract shapes elicit a less pronounced N3 than non-category pictures (Curran et al., 2002). Finally, the component is reduced for pictures showing meaningful vs. non-meaningful hand gestures (Gunter & Bach, 2004; however, a somewhat different scalp topography was reported). Apart from the amplitude, the spread of the component also seems to be affected by the ease of object recognition such that pictures that are more difficult to discriminate are spread over a longer time window (Philiastides et al., 2006).

The N300 is also sensitive to manipulations of relatedness or congruity of a target stimulus with a preceding picture (Barrett & Rugg, 1990; Holcomb & McPherson, 1994; West & Holcomb, 2002; Eddy, Schmid & Holcomb, 2006; McPherson & Holcomb, 1999, exp. 1 &

2) or with a preceding movie clip (Sitnikova et al., 2008). In all the above cases, when the picture is congruent or related to the preceding picture/clip, its N300 amplitude is reduced. Similar reductions occur for pictures containing objects that are congruent vs. incongruent with the surrounding scene (Ganis & Kutas, 2003; Mudrik et al., 2010). However, the relatedness effect is not confined to picture-to-picture contingencies. Similar reductions of the N300 occur for pictures congruent with the preceding word (Chauncey et al., 2009; Blackford et al., 2012; Mazerolle et al., 2007; Koester & Schiller, 2008) or sentences in which the picture stands in for a congruent or incongruent word (Nigam et al., 1992; Ganis et al., 1996; Federmeier & Kutas, 2001, exp 1 & 2; Federmeier & Kutas, 2002; Wicha, Moreno & Kutas, 2003, Wicha, Bates et al., 2003). Importantly, when congruent and incongruent words are presented instead of the pictures, the effect of congruity only results in modulation of the N400 component, but not of the N300 (Nigam et al., 1992, Ganis et al., 1996), which confirms that the component is specifically associated with processing of pictorial stimuli, even though the conceptual content conveyed by the words and pictures depicting them might be similar.

Another factor that affects the amplitude of the N300 is picture repetition. The component is strongly reduced when the same picture is viewed for the second time (Van Petten et al., 2000; Henson et al., 2004; Schendan & Kutas, 2007) or when participants are familiarized with the pictures before the experiment (Federmeier & Kutas, 2001). However, the effect of repetition is decreased when the object in the two presentations is rotated (Schendan & Kutas, 2003). Repetition seems to affect also the latency of the N300. When fragmented but previously identified pictures are presented again, the N300 starts earlier (Viggiano & Kutas, 1998). The sensitivity of the N300 to item repetition is an important feature of this component which should be considered in studies that repeat the same pictures

across an experiment. In this context, it is worth noting that in most ERP studies on language switching, the repetition effect was not explicitly controlled and accounted for.

Finally, the component does not merely reflect passive object recognition. If the task requires accessing some aspects of conceptual knowledge related to a given object, the component reflects the relative difficulty of access to the knowledge, even when the same object is presented in all conditions (Gratton, Evans & Federmeier, 2009; Voss et al. 2010; Philiastides & Sajda, 2006). For example, the amplitude of the component is greater for artifacts that are deprived of a feature that is critical for their functioning, but only when the task at hand requires participants to determine if the artifact can work (Gratton, Evans & Federmeier, 2009). Thus, the N300 seems to reflect visual processing of an object *in the service of the current task*. In other words, the N300 can be observed whenever a task requires object recognition and whenever there is an experimental manipulation of some aspect of difficulty related to the given task. This interaction between the process of object recognition and particular task demands seems to be a common denominator for most of the N300 effects reported in the literature.

The above interpretation of the N300 seems to be additionally supported by evidence from neuroimaging research that aimed to localize its neural generator. The N300 has been linked to occipitotemporal generators, including the object-selective lateral occipital cortex (LOC; Schendan & Kutas, 2002; Doniger et al., 2000; Schendan & Maher, 2009; Schendan & Lucia, 2010; Clarke et al., 2012). Importantly, LOC strongly interacts with other brain regions and the N3 occurs in the time period as when LOC is synchronized with other brain regions (including the ventro-lateral prefrontal cortex; VLPFC; Hopf et al., 2006). Based on neuroimaging findings on the generators of the N300, a two-stage interactive account of visual knowledge has been proposed (Schendan & Kutas, 2007; Schendan & Stern, 2008;

Schendan & Maher, 2009; see also its extension, the MUSI framework, Schendan & Ganis, 2012; 2015). According to the model, the N300 reflects an interactive stage in object processing which involves recurrent computations between areas representing perceptual and abstract knowledge and with the VLPFC selecting aspects of this knowledge that are relevant to current task goals (Schendan and Kutas, 2007; Schendan and Stern, 2008; Schendan & Maher, 2009; Schendan & Lucia, 2010). In the section below, we discuss the implications of the N300 on the interpretation of results from the current study.

How does knowledge about the N300 help in interpreting the results of the present experiment?

In the current experiment we observed that repeated naming of the same picture leads to reduced amplitude of the N300. These results are in fact a direct replication of previous findings (see the section above). Using the theoretical framework described above, it is easy to explain the N300 reduction effect in terms of primed picture recognition. A novel aspect of our results is that the N300 amplitude was also affected by the language of naming in a block that preceded the L1 naming (L1 vs. L2). Importantly, the Preceding Language factor seems qualitatively different from the other factors which in previous studies were shown to determine the N300 because it relates not to the ease of object recognition, but is lexical in nature. We believe that this novel result can be easily accommodated within the overall N300 framework described in the previous sections, according to which the component reflects an interplay between bottom-up object recognition processes and the task at hand.

Because in the current study the task at hand involved picture naming, the observed sensitivity of the N300 to the preceding language implies that the process of picture recognition occurs in synchrony with the word retrieval process of the corresponding name in the target language. Moreover, if accessing the lexical representation of the picture to be

named is difficult, the synchronized process requires more effort⁶, as is reflected in the increased N300 amplitude. In this sense, the sensitivity of the N300 modulation to the language context—as observed in our study—resembles the sensitivity of the N3 modulation to the difficulty in access to task-relevant conceptual knowledge about a depicted object, as reported in previous studies (Gratton, Evans & Federmeier, 2009; Voss et al. 2010; Philastides & Sajda, 2006). In other words, in the case of the *after L1* vs. *after L2* manipulation, the N300 component seems to be informative about the difficulty in retrieving the about-to-be-produced name of the picture (in the case of our task, a name in L1). In the next two sections, we explain how our interpretation of N300 modulation impacts understanding of whole-language and item-specific after-effects.

Whole-language after-effects in the blocked picture-naming paradigm

One of the main goals of the present study was to explore the consequences of language production in L2 on subsequent naming pictures in L1 (L1-after-L2 effect) at the whole-language level. We observed that when pictures in the preceding block were named in L2, subsequent naming of pictures (even those previously unseen) in L1 led to a higher amplitude of the N300, compared to when pictures in the preceding block were named in L1. Given the interpretation of the N300 presented in the preceding section, the results indicate that after a block of picture naming in L2, all lemmas in L1 were more difficult to access. In other words, the observed increase of N300 amplitude is a consequence of processes that occurred earlier, presumably in the preceding block of L2 naming. This raises a question about the possible mechanism that hampered access to L1. Our results, however, are agnostic in this respect and are in line with both explanatory accounts presented in the Introduction, i.e. the Inhibitory

⁶ This mirrors the sensitivity of the N400 effect, which appears to reflect lexical access *and* word recognition (Kutas & Federmeier, 2011).

Control account (Green, 1998) and L2 interference account (Koch, Gade, Schuch, & Philipp, 2010).

Critically, we propose that – contrary to previous interpretations based on interpretation of this component as the no-go N2 (e.g. Misra et al., 2012) – the L1 retrieval difficulty (observed in the delay of L1 responses and increased N3 amplitude in the *L1-after-L2 condition*) does not manifest active inhibition that takes place during the block in which the effect is observed, i.e. during L1 naming. Instead, our claim is that the L1 retrieval difficulty is a *consequence* of processes that took place *earlier*, i.e. during the preceding L2 naming. Thus, our proposed reinterpretation of the observed L1 retrieval difficulty poses an important difference with respect to previous interpretations that were based on identification of the N2 component and which claimed that language inhibition occurs during L1 naming (e.g. Misra et al., 2012).

Item-specific lexical activations in the blocked picture-naming paradigm

Another goal of the present study was to establish if language after-effects occur not only on the level of the whole language, but also on the level of specific items. We hypothesized that if – in addition to lexical representations at the whole-language level – the after-effects also concern specific lexical representations, electrophysiological measurement should allow us to observe an indication of inhibition in the *repeated-after-L2* condition (naming a picture in L1 which was previously named using a different label in L2), relative to the *new-after-L2* condition (naming a new picture in L1 after a block of naming different pictures in L2). In other words, we would expect an interaction between the preceding language and repetition such as *the repeated after-L2 condition* would show the most negative N2.

The ERPs showed no such an interaction. The analysis of the N3 complex amplitude showed additive main effects of repetition and of the preceding language. Moreover, if item-level inhibition acted on top of global inhibition, we would expect the highest N3 amplitude in the *repeated-after-L2* condition. However, it was the *new after-L2* condition that had the highest N3 amplitude. Thus, the ERPs do not support the idea that the after-effects (driven by inhibition or interference) act on the level of specific lexical items.

Differences between behavioral and ERP evidence

The pattern of results for the N3 does not fully align with the pattern of results for naming latencies. Specifically, naming latencies show an interaction between the Preceding Language and Repetition, whereas the ERPs show just main effects but no interaction. Below, we consider possible sources of this dissociation.

Discrepancies between behavioral and electrophysiological measures are not uncommon in the literature because no single ERP component determines reaction times. In particular, the amplitude of the N400 – a component which in many ways is similar to the N300 – is not causally linked to reaction times. First, the N400 (and the N3) occurs even when no reactions are necessary; second, it is easy to dissociate the amplitude of the N400 from reaction latency (see e.g. Fischler et al., 1983; Holcomb, 1993), although the same manipulations often affect both RTs and the N400. The most reliable ERP predictor of reaction times is the latency of the P300 (see e.g. McCarthy & Donchin, 1983; Makeig et al., 1999, 2004), but even this index can be dissociated from the RTs if the manipulation affects post-perceptual stages of the reaction (see e.g. Duncan-Johnson & Kopell, 1981) or in case of complex stimulus–response mappings (Verleger, 1997).

In the case of the experimental manipulation used in the current study, it is likely that the ERP and behavioral measurements captured different aspects of picture naming, which in itself includes several component processes (e.g. perceptual processes related to picture recognition, the subsequent activation of the conceptual and lemma representation during lexicalization, phonological encoding, as well as articulation). The N300 component taps the relatively early stage of picture-naming performance that seems to correspond to lexico-semantic activation. Naming latencies on the other hand, appear to be co-determined by processes that occur at later stages (e.g. decision, phonological encoding, or articulation). The dissociation was present in the case of the *repeated-after-L2* condition, in which a picture previously named in L2 needed to be named in L1. We therefore speculate that the observed decrease of N3 amplitude in the *repeated-after-L2* condition may reflect facilitated access to lexico-semantic information due to picture repetition, while the delayed RTs may reflect a difficulty that occurs at later stages of processing, possibly during phonological or articulatory encoding and execution. As stated before, this difficulty could have resulted from lingering activations of no longer relevant but previously used L2 phonological representations that interfere with phonological representations of L1, or from the inhibition of L1 phonological representations that occurred during L2 naming. It could also result simply from reduced repetition priming (only the concepts but not L1 labels were primed during L2 naming of the same items). In conclusion, regardless of the exact nature of the mechanism, the pattern of dissociation suggests that production of translation equivalents might be hampered specifically at the later stages of language production.

Conclusions: what ERPs (do and do not) tell us about language retrieval difficulty.

In conclusion, we believe that our study provides a number of important insights into our understanding of the processes underlying bilingual picture naming and bilingual

language control. First, it suggests that at least in the blocked picture-naming paradigm, previous studies might have erroneously interpreted their main ERP modulation as the N2 component. Based on a review of ERPs time-locked to picture presentation, we propose that it is more plausible that picture naming is associated with modulations within the N300, a correlate of high-level, goal-driven picture processing. Second, our study extends the existing inventory of the task-dependent factors which are known to influence the N300. Namely, it demonstrates that in the case of picture naming, difficulty accessing the name of a corresponding picture can also lead to increased N300 amplitude. Third, our behavioral and ERP results provide compelling support for the after-effects at a whole-language level; as such, they are consistent with previous reports that employed a similar paradigm and the same neuroimaging technique (e.g. Branzi & al., 2014; Misra et al, 2012), at the same time clarifying some of their methodological shortcomings. Importantly, the identification of the N300 component rather than the N2 component during L1 naming in bilinguals suggests that the L1-after-L2-effect reflects difficulty of access to relevant L1 representations rather than an active inhibitory process that takes places during L1 naming. As the very name implies, language after-effects must be caused by processes that take place in *preceding* blocks of picture naming. The ERP results, however, do not inform the very nature of the process that took place in the L2 production block, which could involve either inhibition of L1 or increased L2 activations which were then carried over to the L1 block.

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